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ABSTRACT

The relationship between hyperactivity and neuropsychological test performance at different age levels was investigated with 90 children 6-8 years old and 92 children 9-12 years old. Subjects were administered a battery of neuropsychological tests, and a parent completed the Child Behavior Checklist (CBC). Young children demonstrated no significant association between hyperactivity/attentional problems (as measured by the Hyperactivity scale of the Child Behavior Checklist) nor between performance on neuropsychological tasks thought to contain an attentional component--Wechsler Intelligence Scale for Children Achievement Test-Revised (WISC-R Coding); Arithmetic, and Digital Span; WRAT Arithmetic; and the Benton Visual Retention Test (VRT). However, for older children, there were significant and large negative correlations between CBC Hyperactivity scores and Coding, WRAT Arithmetic, and Benton VRT scores. Multiple regression analyses supported the above results (for Coding and WRAT Arithmetic), indicating that hyperactivity/inattention has a particularly deleterious effect on test performance (relative to same age peers) as age increases. Results of factor analyses suggested that the factor structure of the WISC-R in samples of children with attentional problems may depend on the age of the children studied. (Author/DB)

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The Mediating Effect of Age on the Relationship Between Hyperactivity and Neuropsychological Test Performance

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Abstract

The relationship between hyperactivity and neuropsychological test performance at different age levels was investigated. It was found that for young children (6 to 8 years of age, n = 90), there was no significant association between hyperactivity/attentional problems (as measured by the Hyperactivity scale of the Child Behavior Checklist) and performance on neuropsychological tasks thought to contain an attentional component (WISC-R Coding, Arithmetic, and Digit Span; WRAT Arithmetic; and the Benton Visual Retention Test). However, for older children (9 to 12 years of age, n = 92), there were significant and large negative correlations between CBC Hyperactivity scores and Coding, WRAT Arithmetic, and Benton VRT scores. Multiple regression analyses supported the above results (for Coding and WRAT Arithmetic), indicating that hyperactivity/ inattention has a particularly deleterious effect on test performance (relative to same-age peers) as age increases. Results of factor analyses suggested that the factor structure of the WISC-R in samples of children with attentional problems may depend on the age of the children studied.

Based on a growing body of empirical evidence, a consensus is emerging among neuropsychological researchers that developmental level is an important variable to consider when investigating the cognitive/behavioral/emotional effects of various childhood disorders (Fletcher & Taylor, 1984). With regard to hyperactivity and attentional problems, the adoption of a developmental focus appears to be crucial in view of the ample physiological and neuropsychological evidence which has accrued concerning the development of attentional abilities in normal children.

As normal children grow older, their orientation changes from exploration to search. Rather than usually seeking novelty and immediate reinforcement, older children are more deliberate, goal-oriented, and controlled by task-defined constraints (Vlietstra, 1982). Miller and Weiss (1981) found that efficient strategies of attention allocation develop primarily between grades 2 and 5 and that processing becomes more selective between grades 5 and 8. The ability to sustain attention increases drastically with age (O'Dougherty, 1986). Susceptibility to various types of distraction also follows a developmental course (Humphrey, 1982). Finally, it is well-established that children become less impulsive with age (Messer, 1976; Paulsen, 1978; Paulsen & Johnson, 1980).

Our understanding of the physiological/neuroanatomical bases of attention has increased dramatically in recent years and it is becoming clear that these physical underpinnings of attention also change as the child matures. There is ample evidence that there are developmental stages in growth and specialization of the frontal lobes (Luria, 1966; Nauta & Feirtag, 1986), which are involved integrally in attentional regulation (Luria, 1973; Mesulam, 1986). Myelinization of neurons in frontal areas and of thalamofrontal tracts does appear to progress slowly and is not completed until the adolescent years (Reines & Goldman, 1980; Yakovlev & Lecours, 1967). In the most comprehensive developmental neuropsychological study of frontal lobe functioning to date, Passler, Isaac, and Hynd (1985) examined the performance of normal children at four age levels from 6 to 12 years. They found that the greatest spurt of development took place between ages 6 and 8 but that complete mastery of a number of tasks involving frontal lobe functioning was not demonstrated even at the 12 year old level.

Given the key role of the frontal lobes in attentional regulation and the parallels in the development of attention and frontal regions, it is not surprising that a number of investigators have postulated that attention deficit disorder involves some type of frontal dysfunction (Mattes, 1980; Rosenthal & Allen, 1978; Stamm & Kreder, 1979). Stamm and Kreder, for example, hypothesize that prefrontal dysfunction would result in inadequate

excitation of inhibitory caudate neurons, leading to impairment in inhibitory control of psychological processes and motor responses. A recent regional cerebral blood flow study lends support to this proposition. Lou, Henriksen, and Bruhn (1984) report that all 11 of the children in their study with ADD exhibited hypoperfusion in the central white matter of the frontal lobes and that 7 of the 11 children showed hypoperfusion in the caudate nuclei region.

The evidence presented above suggests that one needs to address developmental issues when investigating the effects of hyperactivity/attention deficit. Barkley (1981) has noted that although hyperactivity and inattention do not appear to worsen with age, the number and severity of their consequences often increase with age. Evidence for this phenomenon has emerged from both cross-sectional and longitudinal studies. For example, while hyperactive and control groups exhibit comparable IQ scores in the early primary grades (Loney, 1980), beginning about in grade 3, WISC-R scores of hyperactive children have been found to be lower and more variable than controls (Palkes & Stewart, 1972). Weiss, Hechtman and Perlman's (1978) ten-year follow-up evaluation revealed that although adolescent hyperactives' activity level had decreased since their initial assessment as children, their academic performance relative to their peers had declined.

There are clearly several possible explanations for the above-mentioned negative consequences of hyperactivity increasing with age. First, hyperactivity and inattention occurring at an early age may interfere with the acquisition of fundamental knowledge and skills, so that as the child progresses through school he/she may fall further and further behind peers. Second, as the child receives continued negative feedback about his/her behavior and academic achievement, self-esteem, motivation, and expectation of future success are likely to be affected adversely, resulting in a further decrement in social and intellectual functioning. Third, it may be that although the problems of hyperactivity and inattention do not worsen with age, neither do they markedly improve. Thus, relative to their normal peers whose attentional abilities are following an upward developmental course, these children display greater deficits as they grow older. The first two explanations offered above would apply to performance on nearly any kind of cognitive task and would also be relevant to the performance of learning-disabled children who are not hyperactive. The third explanation, however, applies most directly to tasks having a substantial attentional component and does not pertain to learning-disabled children without attentional problems.

Since age appears to be a potentially important mediating variable in the relationship between hyperactivity and its negative consequences, it was decided to investigate the possible effect of age on the association between

hyperactivity and performance on neuropsychological tasks. In order to examine the relative importance of the three explanations outlined above, tests making substantial attentional demands were administered, as well as tests not making such demands.

The following tests were considered to have a strong attentional component: WISC-R Coding, Digit Span, and Arithmetic; WRAT Arithmetic; and the Benton Visual Retention Test (BVRT). The three WISC-R measures make up the Freedom from Distractibility factor which has consistently emerged from factor analyses of the WISC-R across age groups, sex, and racial groups (Kaufman, 1975). This factor, along with the larger Verbal Comprehension and Perceptual Organization factors, has also been found in samples of children referred for learning or behavioral disorders (Lombard & Riedel, 1978; Swerdlik & Schweitzer, 1978).

WRAT Arithmetic was also designated as involving attention to a substantial degree because it clearly involves sustained effort and attention over a relatively long period of time. Also, performance on this test was found to be correlated .37 with Freedom from Distractibility factor scores in a study of 106 children referred for learning or classroom behavioral problems (Stedman, Lawlis, Cortner, & Achterberg, 1978). Undoubtedly, some of this relationship is due to the mathematical ability required in both WISC-R and WRAT Arithmetic, but a significant proportion of the correlation is probably due to the common attentional demands of the tests.

The final test specified as having a substantial attentional component, the Benton VRT, has usually not been conceptualized as tapping attentional ability, but in our clinical observations of children taking this test, we have noticed the difficulties many children with attentional problems have in keeping focused and attending to the figures for the full 10 seconds before the figures are removed from sight. Also, Lezak (1983) does assert that in addition to requiring memory and constructional skills, satisfactory BVRT performance demands adequate attention.

For comparison purposes, 3 WISC-R subtests which do not appear to have a large attentional component--Information, Vocabulary, and Block Design--will be utilized, as well as the Beery Developmental Test of Visual Motor Integration. Based on the developmental arguments presented earlier, it is predicted that there will be significantly larger negative correlations between performance on cognitive tasks and a measure of hyperactivity/inattention for older children than for younger children. One would predict that the difference in the magnitude of the correlations for the older and younger children would be largest for the attentional tests because all three of the previously discussed possible explanations for the negative consequences of

hyperactivity increasing with age apply, whereas for the non-attentional tasks, only the first two explanations apply.

Also, if age does mediate the association between hyperactivity and WISC-R test performance, it may also affect the factor structure of the WISC-R. To investigate this possibility, factor analyses will be performed for groups of younger and older children who have high scores on a measure of hyperactivity/inattention.. It is predicted that the Freedom from Distractibility factor will emerge more strongly in the older group than in the younger group.

Method

Subjects

The subjects were 182 children (137 males and 45 females) ranging in age from 6 years, 0 months to 12 years, 11 months (with a mean of 9 years, 4 months), who were referred for neuropsychological evaluation due to questions concerning learning problems. There were 165 Caucasians, 12 Mexican-Americans, and 5 blacks. With regard to handedness, 161 were right-dominant and 21 were left-dominant.

Criteria for inclusion in the study were the following: 1) Normal corrected or uncorrected vision; 2) Normal hearing; 3) Verbal IQ or Performance IQ or 80 or above on the WISC-R; and 4) No diagnosis of emotional disability or mental retardation.

Measures

The subjects were administered a battery of neuropsychological tests and their parents (usually the mother) completed the Child Behavior Checklist (Achenbach & Edelbrock, 1983). As mentioned previously, the following tests from the battery were utilized in the data analyses of the present study: all of the WISC-R subtests, (Wechsler, 1974); the Arithmetic test from the Wide Range Achievement Test (Jastak & Jastak, 1965); the Beery Developmental Test of Visual-Motor Integration (Beery & Buktenica, 1967); and the Benton Visual Retention Test (Benton, 1974), Administration A (10-second exposure followed by immediate recall). Beery VMI number correct score, Benton VRT correct score and Benton VRT error score were converted to standard scores using norms provided by Knights and Norwood (1980) and Spreen and Gaddes (1969).

Hyperactivity/inattention was measured as a continuous variable through employing the Hyperactivity scale of the CBC, which yields normalized T-scores. In the CBC manual, Achenbach & Edelbrock report that in a non-clinical sample of 6 to 11 year old boys, the mean Hyperactivity score

was 57.60 (SD = 4.80), while the mean score in a corresponding clinical sample was 68.50 (SD = 9.30). The Hyperactivity scale was not used to diagnose the hyperactive (attention deficit) syndrome, but rather to assess the degree to which behaviors thought to be related to hyperactivity were present. Thus, children with high scores on this scale were rated by their parent as exhibiting many hyperactive-type behaviors (e.g. impulsive, can't concentrate).

Results

For our initial analysis, the sample was split into two age groups. The younger group consisted of 90 children (64 males and 26 females) between the ages of 6 years, 0 months and 8 years, 11 months while the older group contained 92 children (73 males and 19 females) between the ages of 9 years, 0 months and 12 years, 11 months. The means and standard deviations of the younger and older groups on the experimental variables (as well as Verbal IQ, Performance IQ and Full Scale IQ) are presented in Table 1. The only significant differences between groups emerged on the 'attentional' measures of Coding, WRAT Arithmetic, Benton VRT (correct), and Benton VRT (errors). Consistent with the experimental hypotheses, the older children did worse on these measures.

Next, the correlations between CBC Hyperactivity scores and neuropsychological test scores were computed within each of the age groups. Table 2 reveals that in the younger group, all of the correlations were very small and not significant ($p > .05$). However, in the older group, for 4 of the 6 'attentional' measures (Coding, WRAT Arithmetic, Benton VRT-correct, and Benton VRT-errors) there were significant and large negative correlations, indicating that as the older children's Hyperactivity scores increased their performance on these neuropsychological tests worsened. Among the 'non-attentional' tests, only Vocabulary exhibited a significant negative correlation with Hyperactivity and even this correlation was only barely significant ($p = .048$). It is worth noting that unlike the Benton VRT, the Beery VMI Test did not exhibit the pattern of greater negative correlation in the older group than in the younger group. Thus, the attentional component rather than the constructional requirements of the Benton VRT is probably responsible for the emergence of this pattern.

Utilizing the Fisher r to Z transformation, it was found that the correlations involving Coding, WRAT Arithmetic, and Benton VRT (correct) were significantly greater in the older group than in the younger group. The difference for Benton VRT (errors) was only marginally significant ($p < .10$). None of the differences exhibited by the remaining measures were even marginally significant, including that of Vocabulary. Thus, in accord with the

hypotheses, it is evident that older children exhibited a significantly greater negative relationship between hyperactivity/inattention and performance on most neuropsychological tests including a substantial attentional component than did younger children.

In order to avoid the artificial dichotomization of age, multiple regression analyses were also performed in which CBC Hyperactivity T-score, age, and the Hyperactivity X age interaction were regressed on test score. These analyses revealed that the Hyperactivity x age interaction contributed a significant ($p < .05$) amount of unique variance accounted for in Coding and a nearly significant ($p < .10$) amount in WRAT Arithmetic, in spite of the high correlations between the interaction term and the other predictors, which made achieving significance difficult. These results parallel those of the simple correlational analysis, suggesting that as age increases, hyperactivity/inattention is associated with increasing levels of impairment on tests requiring attention.

Next, the factor structure of the WISC-R in younger and older children with high scores on the CBC Hyperactivity scale ($T \geq 70$) was examined. Because only 112 of the 182 subjects were administered Digit Span, it was decided to delete this subtest from the factor analyses and substitute WRAT Arithmetic, since from the correlational analyses, WRAT Arithmetic does appear to have a strong attentional component.

Standard computer-based factor analytic procedures were utilized. Factors determined to account for a substantial proportion of the variance, based on Cattell's (1966) Scree Test, were retained and rotated. All of the retained factors had eigenvalues ≥ 1.0 and all of the discarded factors had eigenvalues ≤ 1.0. Orthogonal (VARIMAX) rotations were performed, resulting in uncorrelated factors.

The factor matrices obtained from the younger ($n = 38$) and older ($n = 35$) samples are presented in Table 3. The numbers in the table are factor loadings, which are the correlation coefficients between factors and variables. In the young group, only the Verbal Comprehension and Perceptual Organization factors emerged. Contrary to the results found in previous factor analytic studies of the WISC-R reviewed earlier, no Freedom from Distractibility factor was obtained. This may be partly due to Digit Span not being included in the present investigation. WRAT Arithmetic loaded most strongly on the Verbal factor.

For the older group, however, three factors did emerge--the usual Verbal Comprehension and Perceptual Organization factors as well as a very interesting third factor. Coding loaded very highly on this factor, but WRAT Arithmetic also had a substantial loading, as did Picture Arrangement.

WISC-R Arithmetic, though, did not load on this factor. This third factor may be tapping the ability to sustain attention. Although Picture Arrangement is usually not thought of as being an attentional task, it is interesting to note that it displayed the same pattern of results as the attentional tests in the previous correlational analyses. The correlation between Picture Arrangement and Hyperactivity score was only -0.15 ($p > .10$) in the young group, but was -0.30 ($p < .01$) in the older group.

Discussion

The results suggest that age is indeed an important mediating variable in the relationship between hyperactivity and performance on neuropsychological tests with attentional demands. It should be noted that the sample which was employed provided a conservative, stringent test of the experimental hypotheses. Many of the subjects included in the study were children who were experiencing learning problems but were not diagnosed as having attention deficit disorder. Thus, many children could have done poorly on Coding, for example, not because of any attentional dysfunction, but because of sequencing, graphomotor and/or symbol manipulation problems. This probably diluted the relationships between the hyperactivity/inattention measure and 'attentional' test performance. The emergence of highly significant findings, in spite of this attenuation, suggests that these results are quite robust.

Because the age effect was evident for most of the attentional measures but not for the non-attentional tests, support was also given to the notion that while young children with attentional problems may not exhibit deficits on tasks requiring attention relative to same-age peers without such problems (because these peers are themselves at a low level of attentional development), as they grow older, their attentional abilities may develop at a slower than normal rate, with the result being more and more impairment relative to peers. Whether these 'lagging' neurodevelopmental processes underlying attention continue until normal maturational levels are reached or stabilize at below-normal levels is an empirical question. It is becoming clear, though, that for a substantial proportion of these children, attentional and social problems persist into the adolescent and adult years (Kinsbourne, 1985; Klee & Garfinkel, 1981).

The finding that the Benton VRT, but not the Beery VMI Test, exhibited the same pattern of results as that of tests requiring sustained attention (Coding and WRAT Arithemtic) supported the original contention that the Benton does have an important attentional component. Thus, when interpreting a poor Benton performance, it is wise to consider the attentional abilities of the child, as well as his/her memory and constructional skills.

It is interesting to speculate why WISC-R Arithmetic and Digit Span did not display the pattern of the other 4 attentional tasks. The negative findings for Digit Span may not be too surprising, since it has been found that even patients with massive bifrontal pathology may not exhibit impaired digit span performance (Benson, Gardner, & Meadows, 1976; Stuss, Alexander, Lieberman, & Levine, 1978). In future studies it may be wise to focus only on Digits Backward, which seems to require much more effortful attention than Digits Forward and in light of the finding of Risberg and Ingvar (1973) that there is marked activation of large areas of prefrontal cortex during digits backward testing.

The negative finding with WISC-R Arithmetic is harder to explain. It may be that the verbal interaction between the examiner and the child serves to focus attention on the task. During Coding, WRAT Arithmetic, and the Benton VRT, the child's attention must be more self-directed and there is less formal opportunity for the examiner to redirect a child's wandering attention back to the task.

The results of the factor analyses indicated that the factor structure of the WISC-R (when WRAT Arithmetic is substituted for Digit Span) found in samples of children displaying hyperactivity/inattention may depend on the age of the children. The usual Freedom from Distractibility factor did not emerge in the sample of younger children, but in the sample of older children, a 'Sustained Attention' factor was obtained. Coding had a very high loading on this factor, more than double its median loading on the Freedom from Distractibility factor in the analyses done by Kaufman (1975) using normal children. WRAT Arithmetic and Picture Arrangement also exhibited moderate loadings on this factor. While these factor analytic results are interesting and of potential theoretical importance, they must be considered merely suggestive at this point because of the small ratio of subjects to variables in the analyses. Replications with larger numbers of subjects are obviously needed.

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Table 1

Neuropsychological Test Performance of Children in the Younger (Age 6 - 8) and Older (Age 9 - 12) Age Groups

Measure	Younger Children			Older Children		
	n	M	SD	n	M	SD
Verbal IQ	90	99.63	16.99	92	100.60	14.96
Performance IQ	90	103.47	16.61	92	99.90	18.22
Full-Scale IQ	90	101.62	16.62	92	100.13	15.64
Coding*	88	9.08	3.10	91	8.15	2.99
WISC-R Arithmetic	90	8.60	3.00	91	8.64	2.85
Digit Span	53	8.77	2.64	59	8.15	2.74
Information	90	9.68	3.42	92	9.84	2.76
Vocabulary	90	10.19	3.65	92	10.00	2.77
Block Design	69	10.69	3.48	92	10.04	3.74
WRAT Arithmetic*	88	97.44	13.15	92	86.98	11.36
Benton (correct)*	48	96.17	17.54	52	87.90	20.03
Benton (errors)*	48	92.04	21.14	52	82.14	20.33
Beery VMI	69	91.10	14.16	60	94.27	15.62
CBC Hyperactivity	90	68.78	8.78	92	66.99	9.95

*Means of groups differ significantly at $p < .05$, two-tailed.

Table 2

Correlations Between CBC Hyperactivity Score and Neuropsychological Test Performance in the Younger and Older Age Groups

Measure	Younger Children		Older Children	
	n	Pearson r	n	Pearson r
Coding'	66	-0.13	91	-0.42**
WISC-R Arithmetic	90	-0.08	91	-0.17
Digit Span	53	0.02	59	-0.20
Information	90	-0.18	92	-0.16
Vocabulary	90	-0.13	92	-0.21*
Block Design	89	-0.13	92	-0.12
WRAT Arithmetic'	66	-0.07	92	-0.30**
Benton (correct)'	46	0.01	52	-0.39**
Benton (errors)	46	-0.06	52	-0.31*
Beery VMI	69	-0.09	60	-0.14

*Correlation significantly different from zero at $p < .05$, two-tailed.

**Correlation significantly different from zero at $p < .01$, two-tailed.

'Correlations of groups differ significantly at $p < .05$, one-tailed.

Table 3

Factor Structure of the WISC-R (Substituting WRAT Arithmetic for Digit Span) in Younger and Older Children With CBC Hyperactivity Scores ≥ 70

	Younger Children[a]		Older Children[b]		
Measure	Factor I	Factor II	Factor I	Factor II	Factor III
Information	.83	.20	.68	.12	.15
Similarities	.81	.16	.76	.13	-.02
Vocabulary	.82	.47	.71	.21	.10
Comprehension	.68	.38	.79	38	.15
WISC-R Arithmetic	.61	.26	.77	.19	.07
Pic. Completion	.51	.67	.31	.66	.27
Pic. Arrangement	.40	.43	.30	.34	.37
Block Design	.21	.75	.44	.63	.17
Object Assembly	.16	.64	-.01	.99	-.02
Coding	.18	.48	.05	.12	.90
WRAT Arithmetic	.65	.34	.63	.00	.41

Note. The numbers in the table are factor loadings on Factor I (Verbal Comprehension), Factor II (Perceptual Organization), and Factor III (Sustained Attention).

[a] n = 38. [b] n = 35.

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